Jetstream 31 (J31) at Mid-Campaign in INTEX-ITCT:

Measurements of Aerosol, Cloud, and Surface Radiative Properties and Effects

Phil Russell, Peter Pilewskie, Jens Redemann, Manfred Wendisch, John Livingston, Jim Eilers, Beat Schmid, Allen Chu, & The Rest Of The J31 Team

ICARTT Mid-Campaign Science Meeting
Portsmouth, NH, 24 Jul 2004

Acknowledgments of Funding

Jetstream mods & ops (Sky Research task order)

- NASA Tropospheric Chemistry Program
- NASA Radiation Sciences Program
- NASA Suborbital Science Program

Measurements, data reduction, & archival

- NOAA Atmospheric Chemistry & Climate Program
- NASA Tropospheric Chemistry Program
- NASA Radiation Sciences Program

Integrated analyses

- NASA EOS Interdisciplinary Science Program
- NASA Radiation Sciences Program

J31 in INTEX-ITCT – Aerosol Direct & Indirect Radiative Effects

GOALS

Assess the radiative impact of the aerosols advecting from North America out over the Northwestern Atlantic Ocean.

- –Clear-sky Impact: Aerosol Direct Effect
- –Impact Via Clouds: Aerosol Indirect Effect

Quantify the relationships between aerosol concentration/composition and aerosol radiative impact.

Contribute water spectral albedo measurements to help improve satellite aerosol retrievals

INTEX-ITCT-ICARTT Provides a Very Fertile Context For Aerosol-Climate Studies

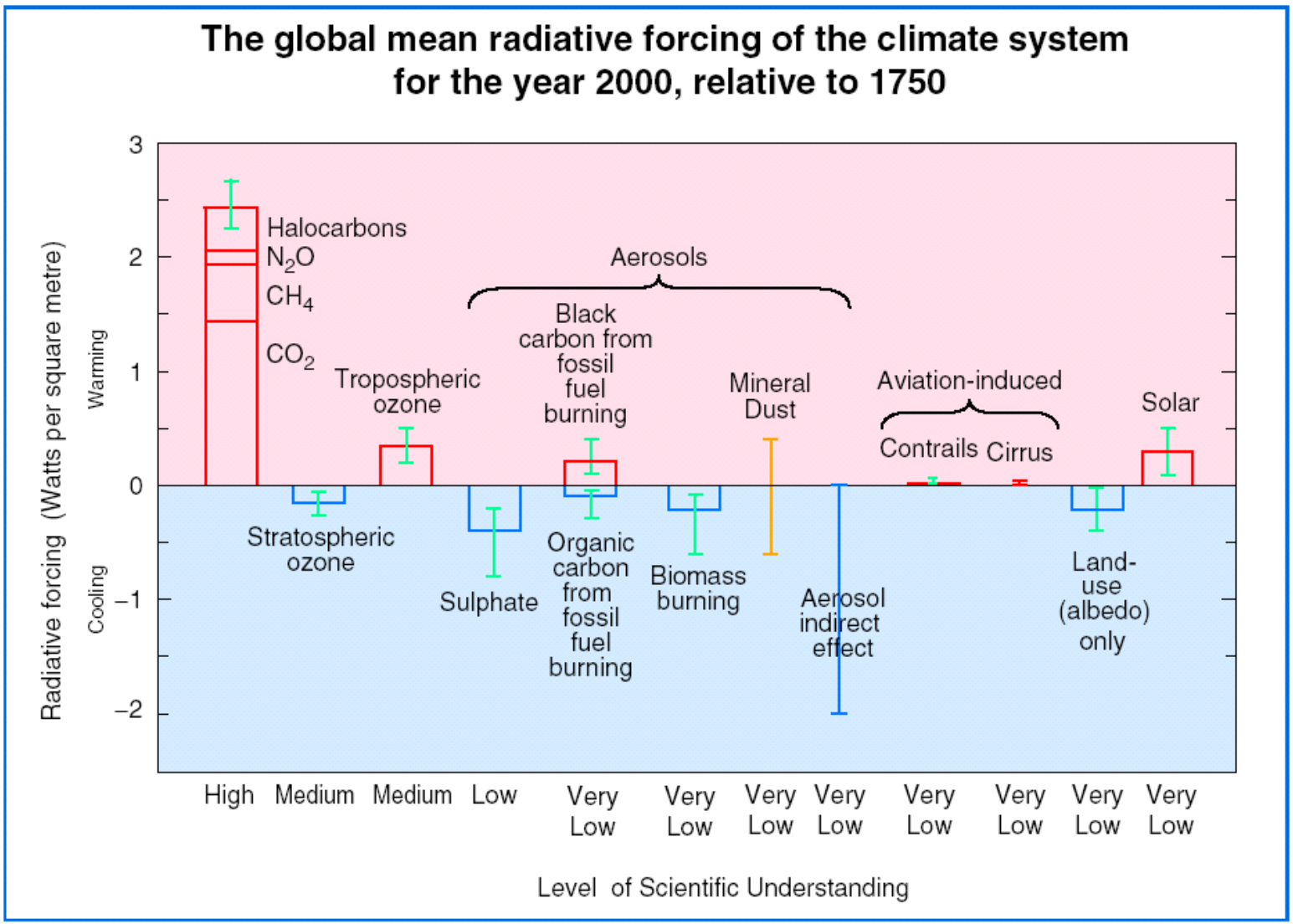


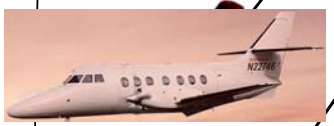
Figure 3: Many external factors force climate change.

- Nearly All The Important Aerosol Types

- Good Mix of Cloudy & Clear Conditions —Direct & Indirect

Satellites

up-and downwelling radiative fluxes



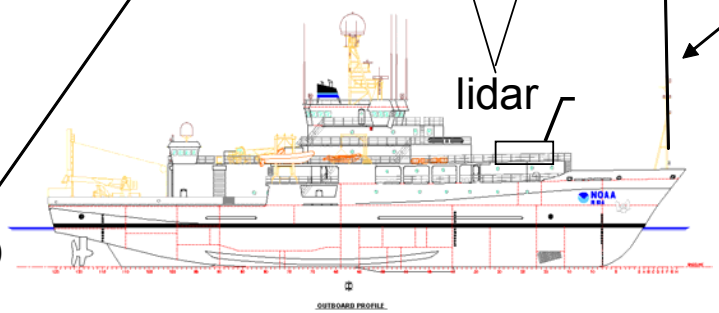
AOD

J31

NOAA Lidar

lidar

extinction profiles



lidar

AOD

up- and downwelling radiative fluxes

P3

DC8

downwelling radiative fluxes and AOD

In-situ measurements of aerosol chemical, physical, optical, f(RH) properties.

Direct Radiative Effects:
What is the clear-sky radiative impact of the aerosols advecting from North America out over the Northwestern Atlantic Ocean?

Ronald H. Brown & Chebogue Point

Jetstream-31 in INTEX-ITCT

Primary Science Instruments

- **14-channel Ames Airborne Tracking Sunphotometer (AATS-14).**

  Co-PIs: Phil Russell, Beat Schmid, Jens Redemann

- **Solar Spectral Flux Radiometer (SSFR).**

  PI: Peter Pilewskie

Jetstream-31 in INTEX-ITCT

- 14-channel Ames Airborne Tracking Sunphotometer (AATS-14)

Measures: Solar direct-beam transmission, T, at 14 wavelengths, λ, 353-2139 nm

Data products

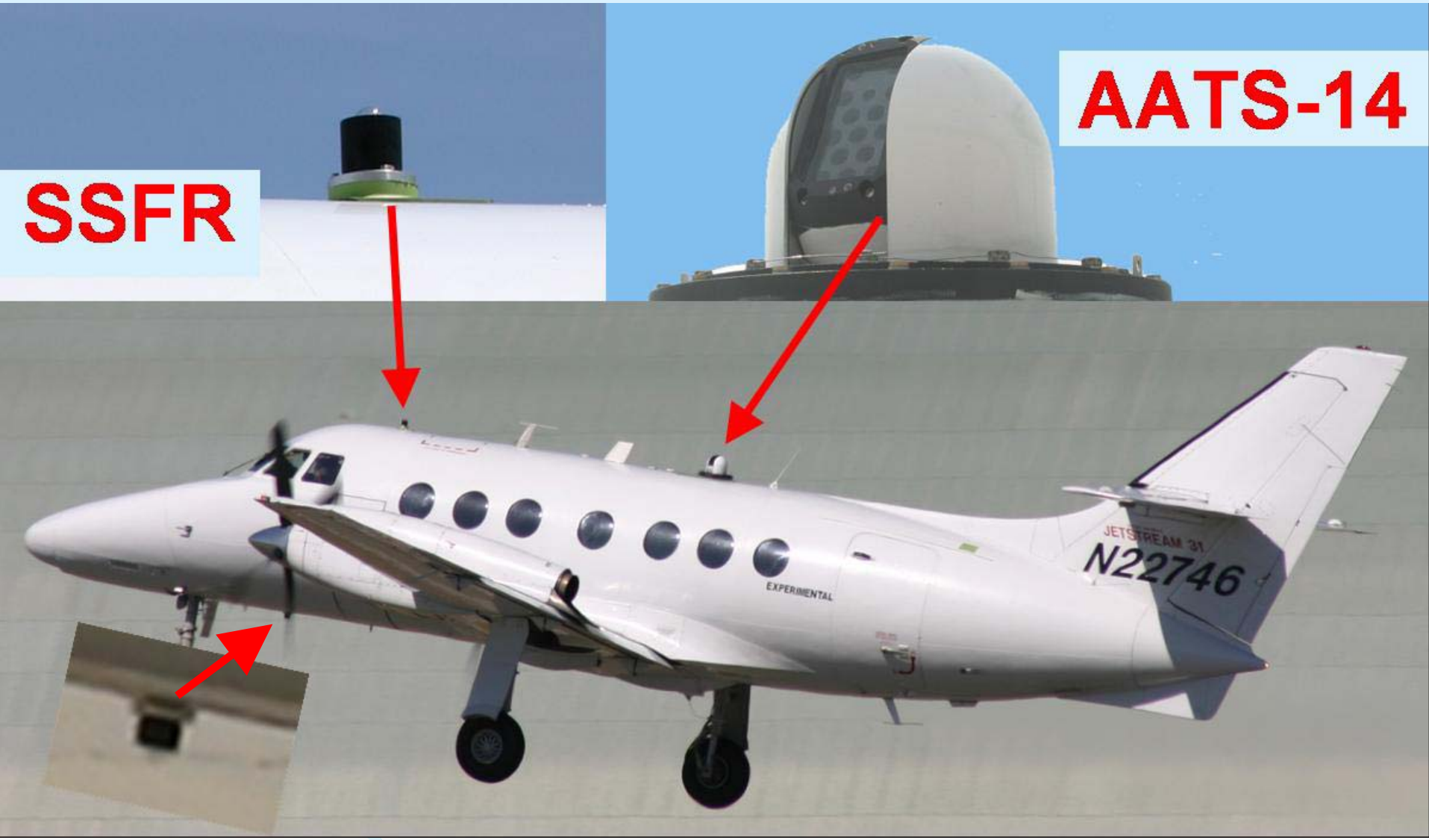
- Aerosol optical depth (AOD) at 13 λ, 353-2139 nm
- Water vapor column content [using T(940 nm)]
- Aerosol extinction, 340-2139 nm
- Water vapor density

} When A/C flies vertical profiles

NASA Ames Solar Spectral Flux Radiometer (SSFR)

- wavelength range: 300 nm to 1700 nm
- spectral resolution ~ 8-12 nm
- simultaneous zenith and nadir viewing hemispheric FOV
- Accuracy: ~ 3%; precision: 0.5%
- Missions: FIRE/SHEBA, DOE ARM UAV (1999, 2000, 2002), PRIDE, SAFARI-2000, ACE-Asia, CRYSTAL-FACE, DOE Aerosol IOP

Jetstream-31 (J31) in INTEX-ITCT



ICARTT Mid-Campaign Science Meeting
Portsmouth, NH, 19 Jul 2004

AATS-14 Science Objectives

- Satellite Validation
- Testing Closure (Consistency) among Suborbital Results
- Testing Chemical-Transport Models Using AOD Profiles
- Assessing Regional Radiative Forcing by Combining Satellite and Suborbital Results

- Joint with SSFR

- Deriving Aerosol Radiative Forcing from Simultaneously Measured Radiative Flux and AOD Gradients
- Providing Over-Cloud AOD Spectra for Analysis with SSFR Measurements of Cloud Albedo
- Deriving Spectra of Aerosol Absorbing Fraction (1-SSA) from Spectra of Radiative Flux and AOD

ICARTT SSFR J-31 Objectives

Cloud Remote Sensing and Aerosol Indirect Radiative Forcing

- Retrieve cloud droplet radius, optical depth, and liquid water path
- Compare/validate with P-3 MIDAS, P-3 microphysics, with satellite retrievals (MODIS), microwave/radar retrievals from the Ron Brown.
- Influence of aerosols on cloud radiative forcing: AATS-14 extinction above cloud, RB lidar extinction below

ICARTT SSFR J-31 Objectives

Cloud-Free Column Closure Studies

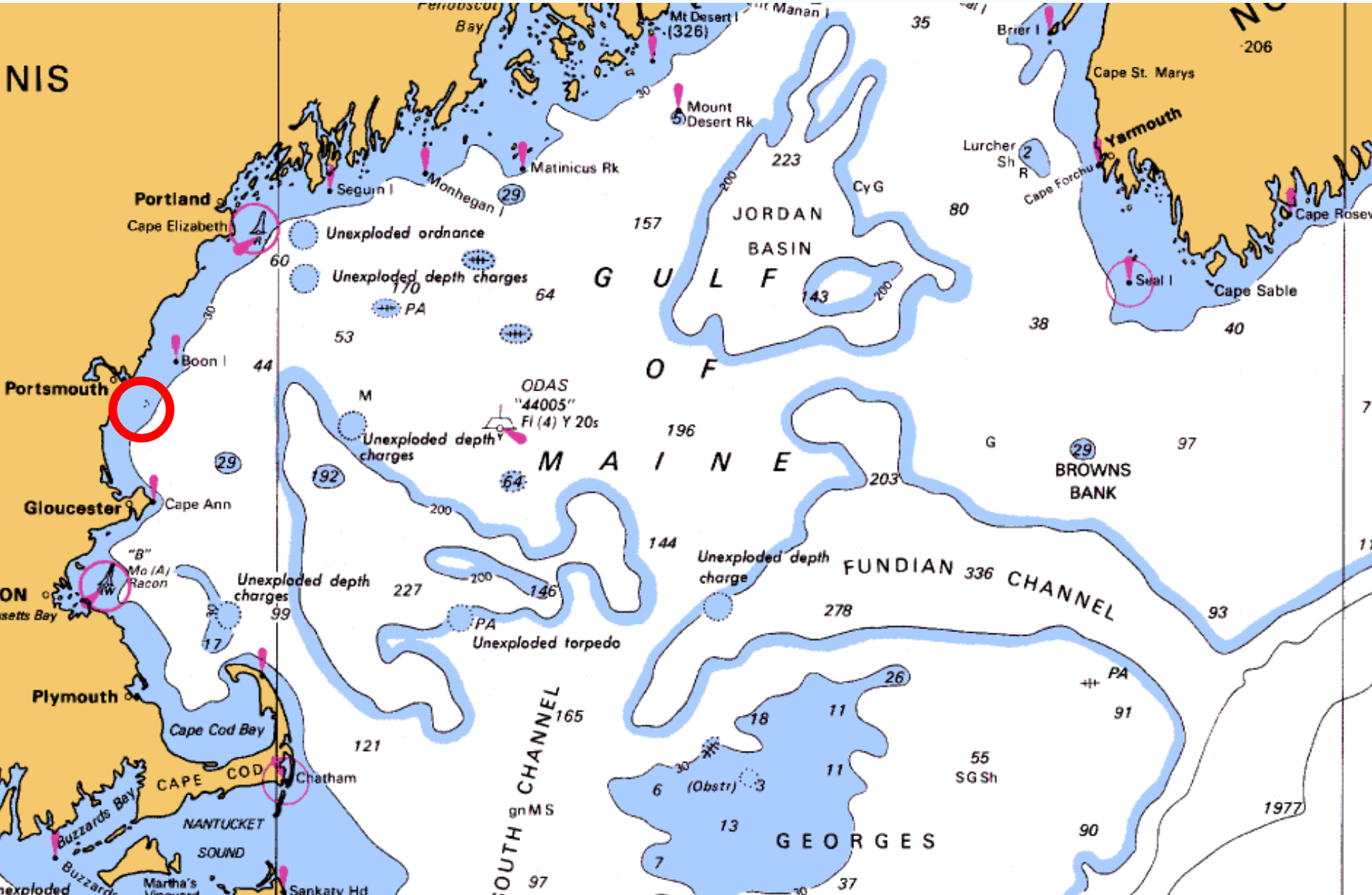
- Measuring spectrally and vertically resolved net solar irradiance → link aerosol radiative effects to optical, microphysical and chemical properties
- Determine column solar radiative boundary conditions for modeling studies
- Combine with AATS-14 aerosol optical depth spectra, derive spectra of aerosol absorption coefficient and single scattering albedo for thick polluted layers.
- Quantify aerosol direct radiative forcing

ICARTT SSFR J-31 Objectives

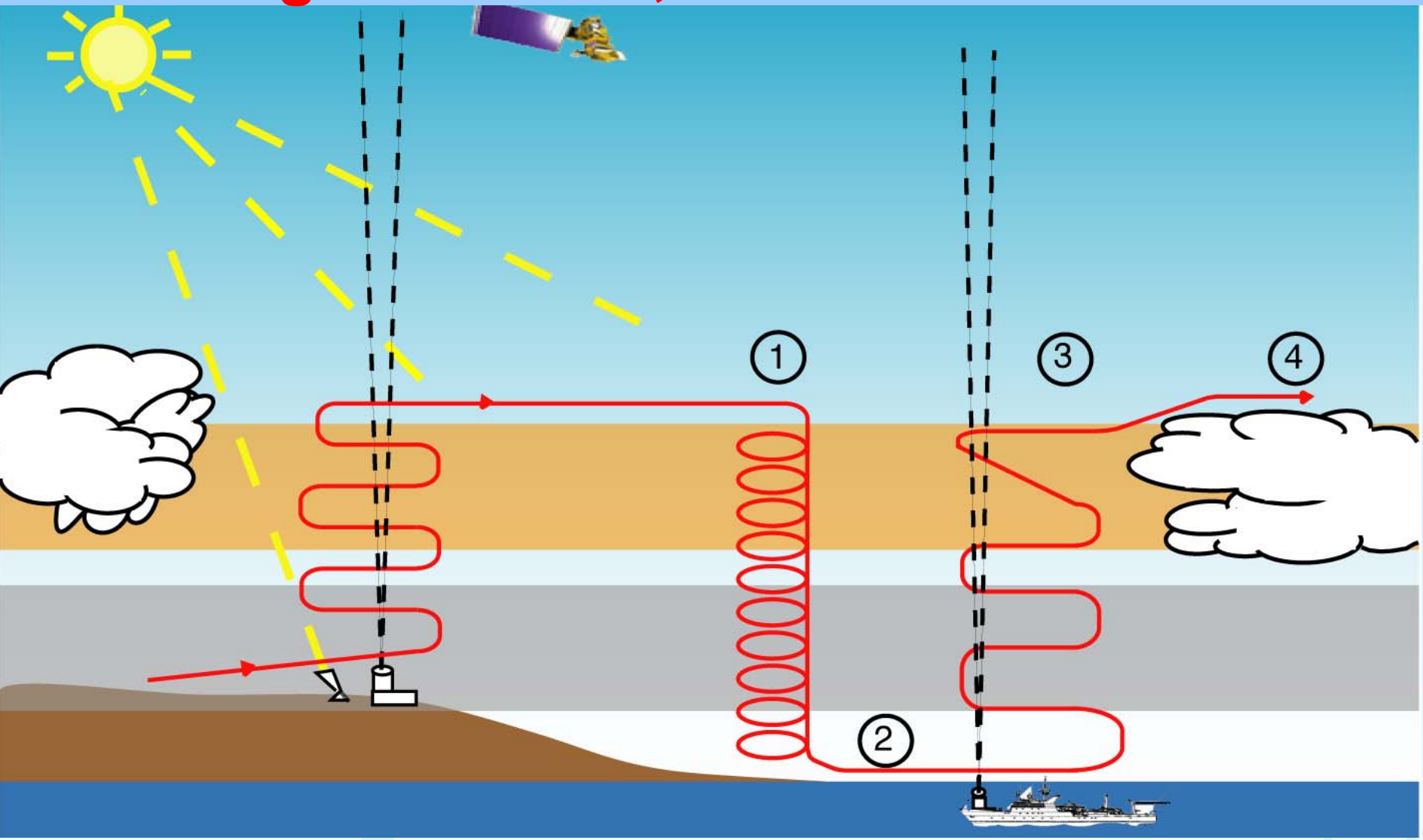
Water-Leaving Irradiance: MISR Validation

- MISR typically uses only the red and near-infrared "dark water" bands for its aerosol retrievals
- Ocean surface reflectance is ***assumed*** negligible in dark bands; not always negligible in the green and the blue, especially for low aerosol optical depth
- MISR team is developing an algorithm to simultaneously retrieve surface reflectance and aerosol properties over shallow polluted waters
- For low aerosol optical depth cases the sea surface albedo contributes the largest uncertainty.

R/V Ron Brown Operations Area



Flight Patterns, J31 in INTEX-ITCT



(1) Survey Vertical Profile. (2) Minimum- Altitude Transect.
(3) Parking Garage. (4) Above-Cloud Transect.

J31 Science Flights out of Portsmouth

Flt No.	Date, Jul 04	Track	Comments
7	12	Western Gulf of Maine	Aqua underflight with profiles, Ron Brown rendezvous
8	15	Western Gulf of Maine	Stratus clouds with Ron Brown & Terra, profiles with 2 RB sondes and Aqua
9	16	Western & Central Gulf of Maine	Profiles and near-surface leg with Aqua & near Ron Brown & its sonde
10	17	Western Gulf of Maine	Profiles and near-surface leg with Terra & near Ron Brown
11	20	Western Gulf of Maine	Stratus clouds with Ron Brown & Terra (MISR local mode).
12	21	Western Gulf of Maine	Aerosol profiles and near-surface leg with Aqua. Aerosol gradient at several altitudes.
13	22	Western Gulf of Maine	Aerosol profiles and near-surface leg with Ron Brown, DC-8, & Terra (MISR local mode).
14	23	Western Gulf of Maine	Aqua underflight with profiles

Example Results

- 3 Cloud-Free Results (Aerosol Direct Effect)
  - Plus a Water Surface Albedo Spectrum Result

- 2 Cloud-Oriented Results (Aerosol Indirect Effect)
  - Plus a P-3 Cloud Result

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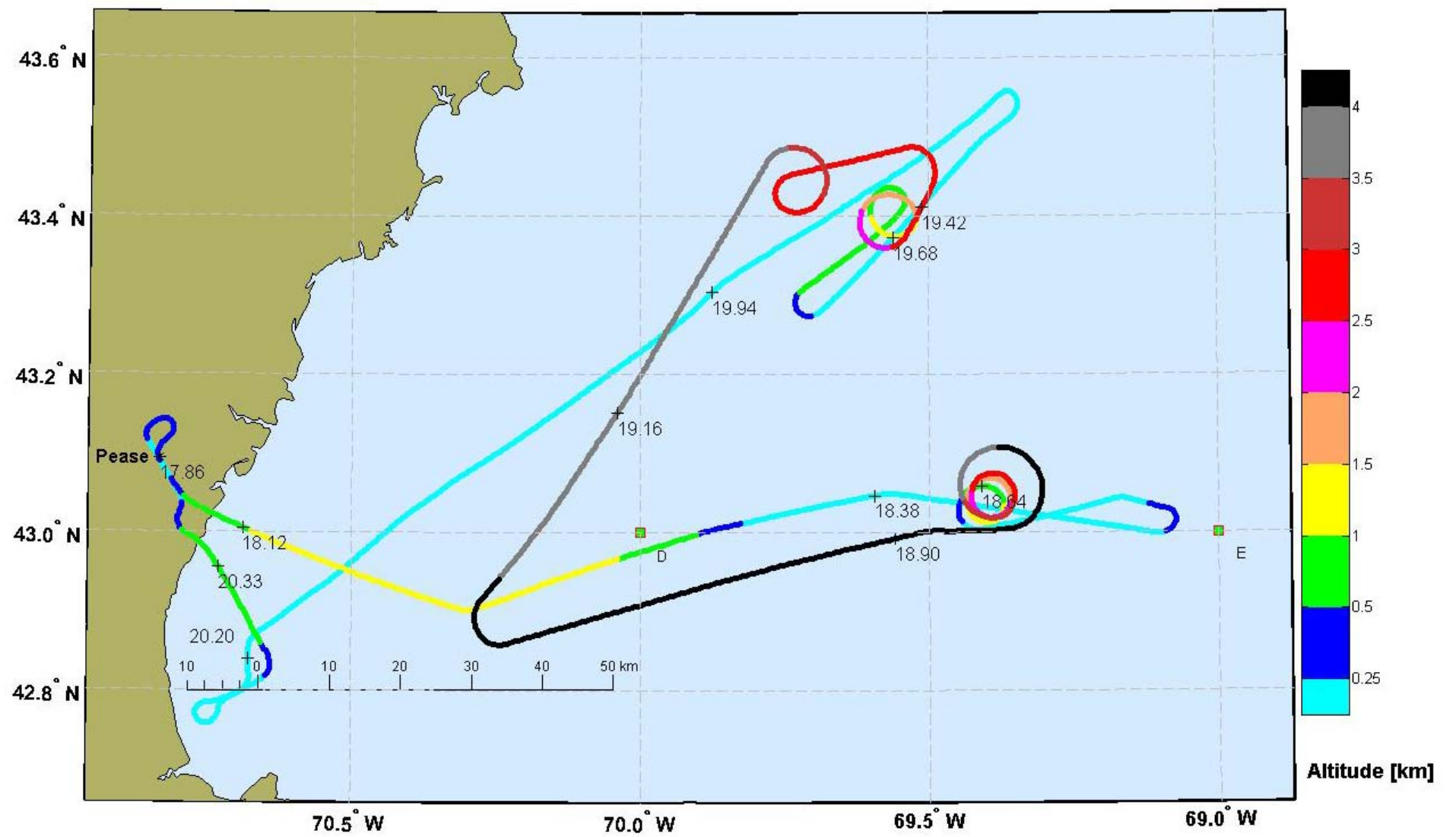
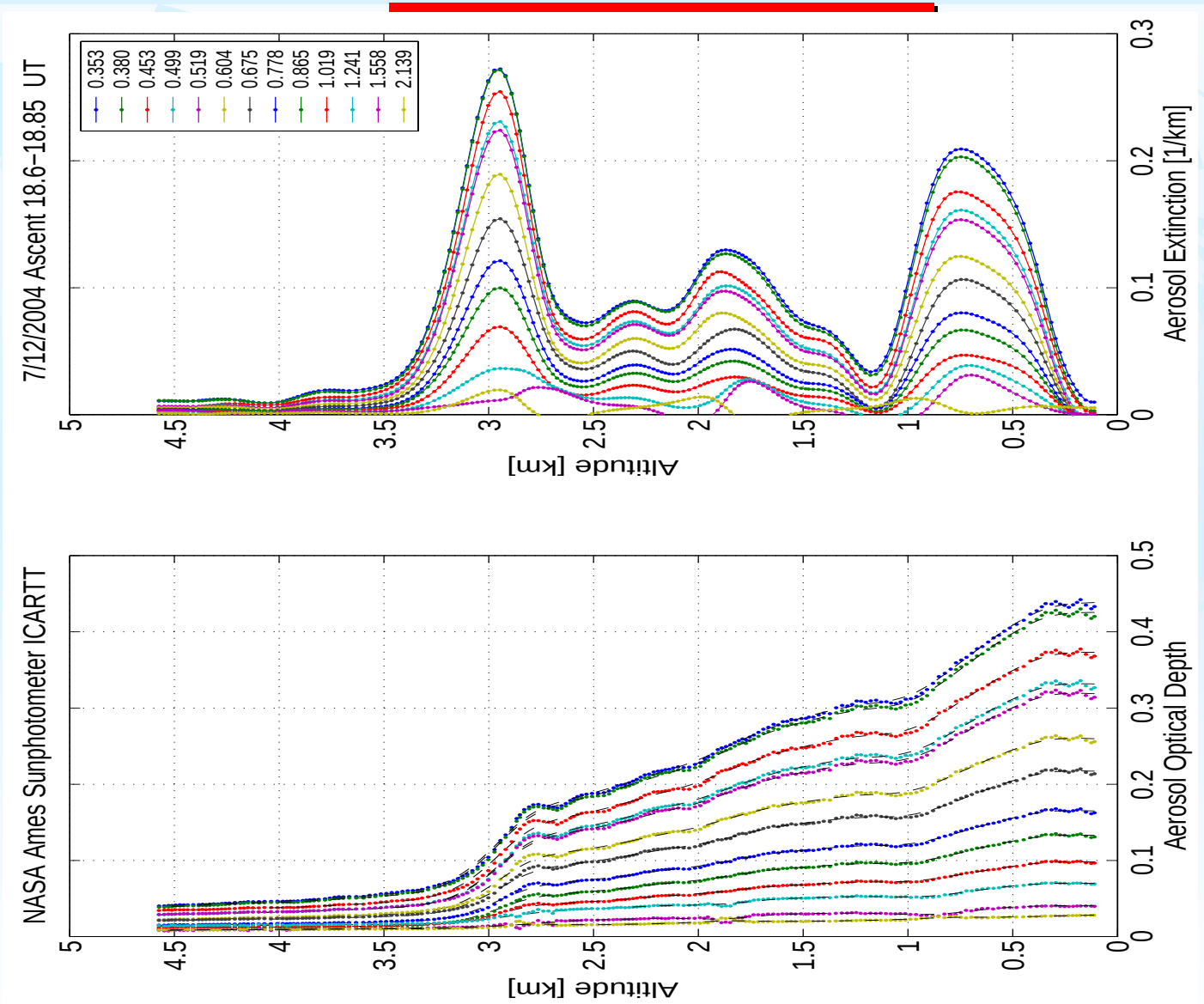
J31 Flight 7, 12 July 2004



J31 Flight 7, 12 July 2004
AATS Results



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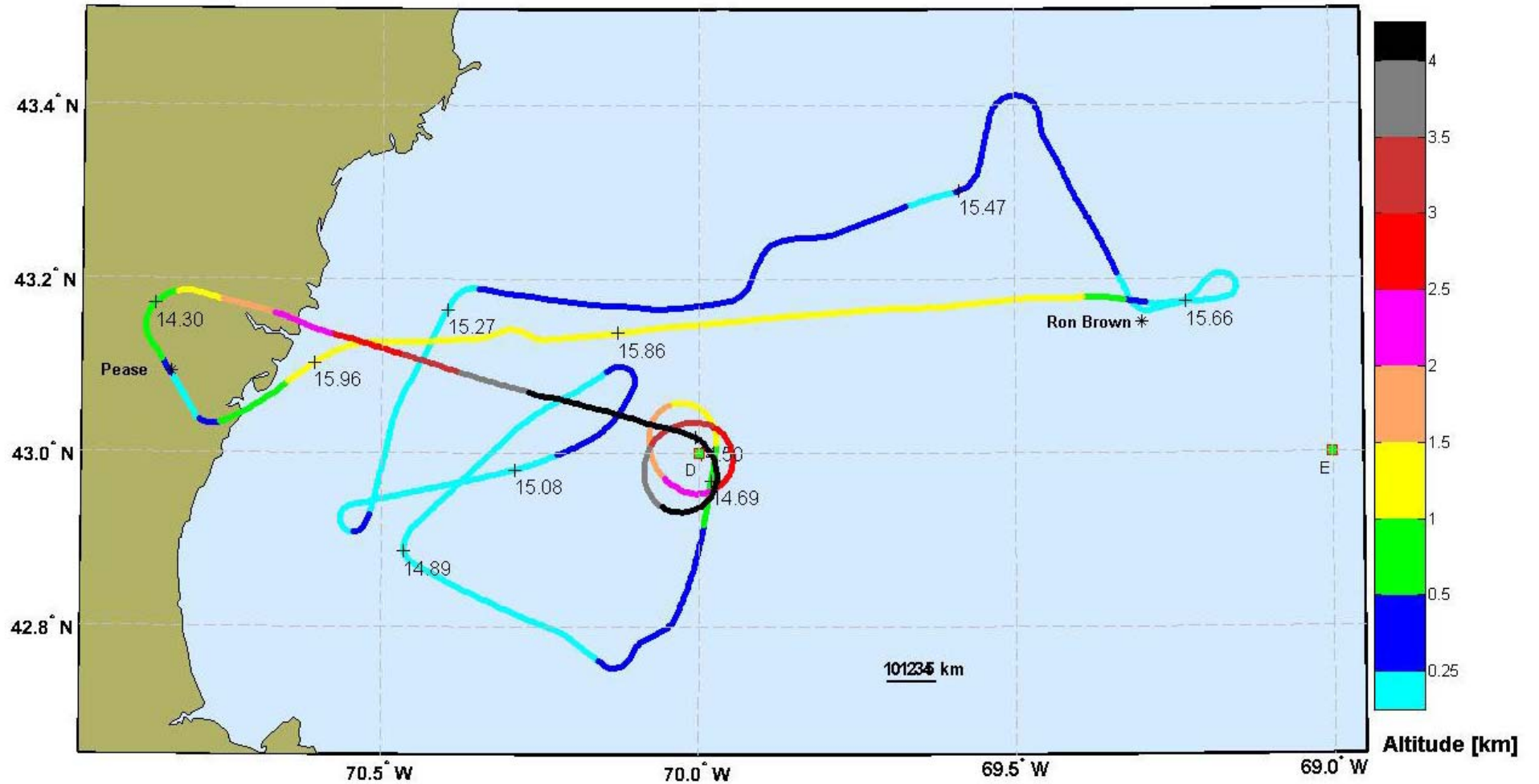
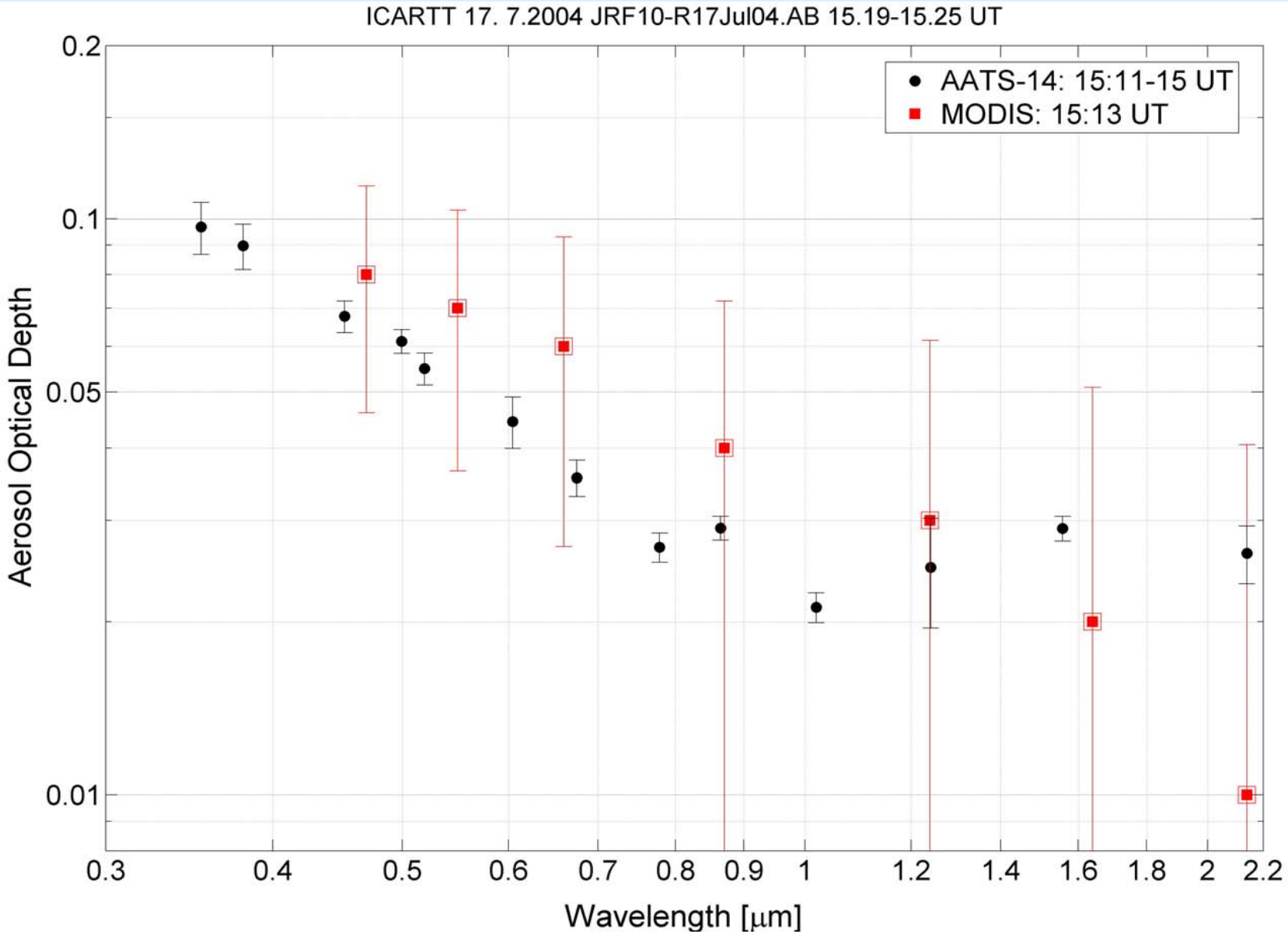
J31 Flight 10, 17 July 2004



J31 Flight 10, 17 July 2004



MODIS-Terra AODs courtesy of Allen Chu

J31 Science Flights out of Portsmouth

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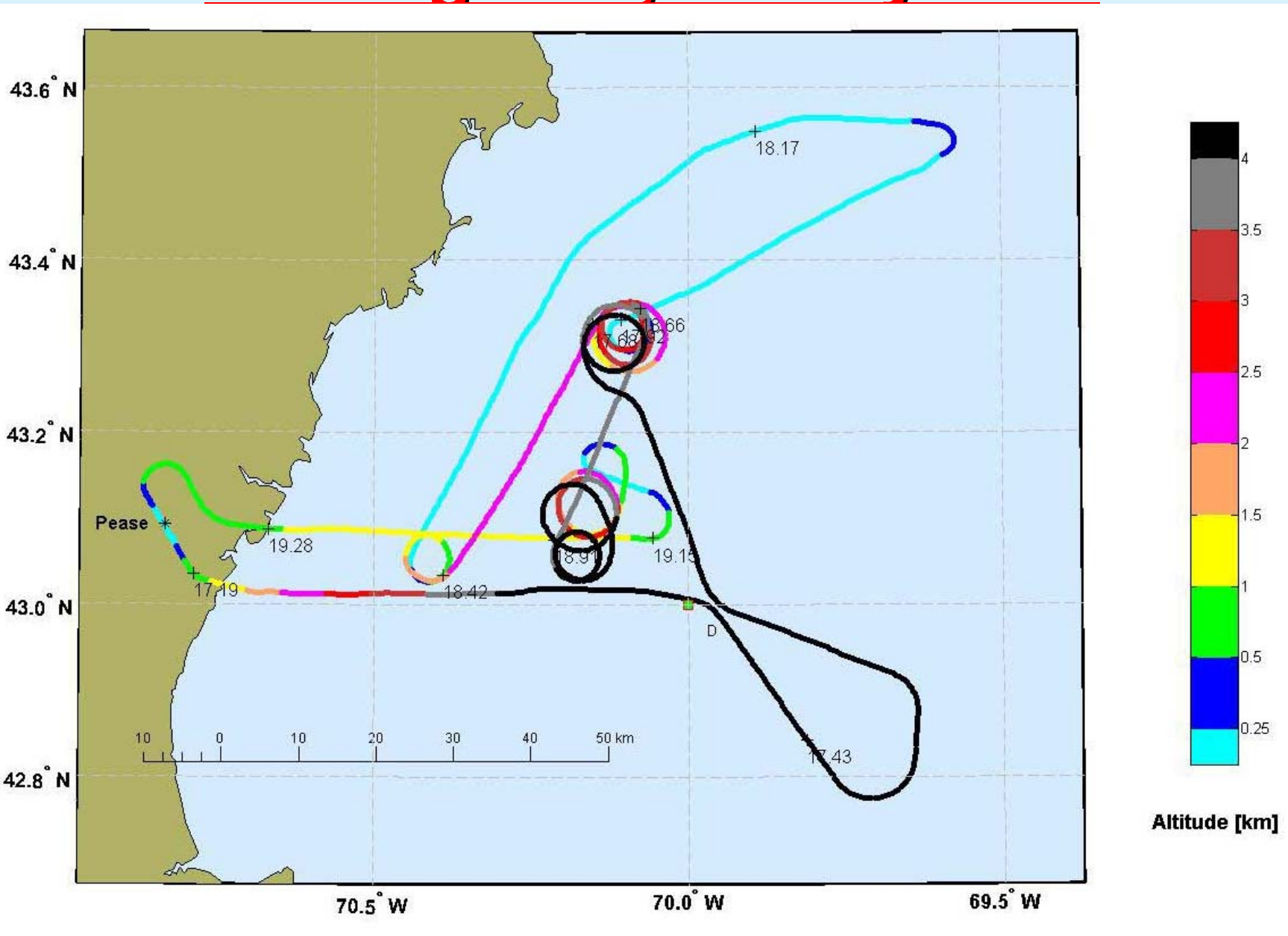
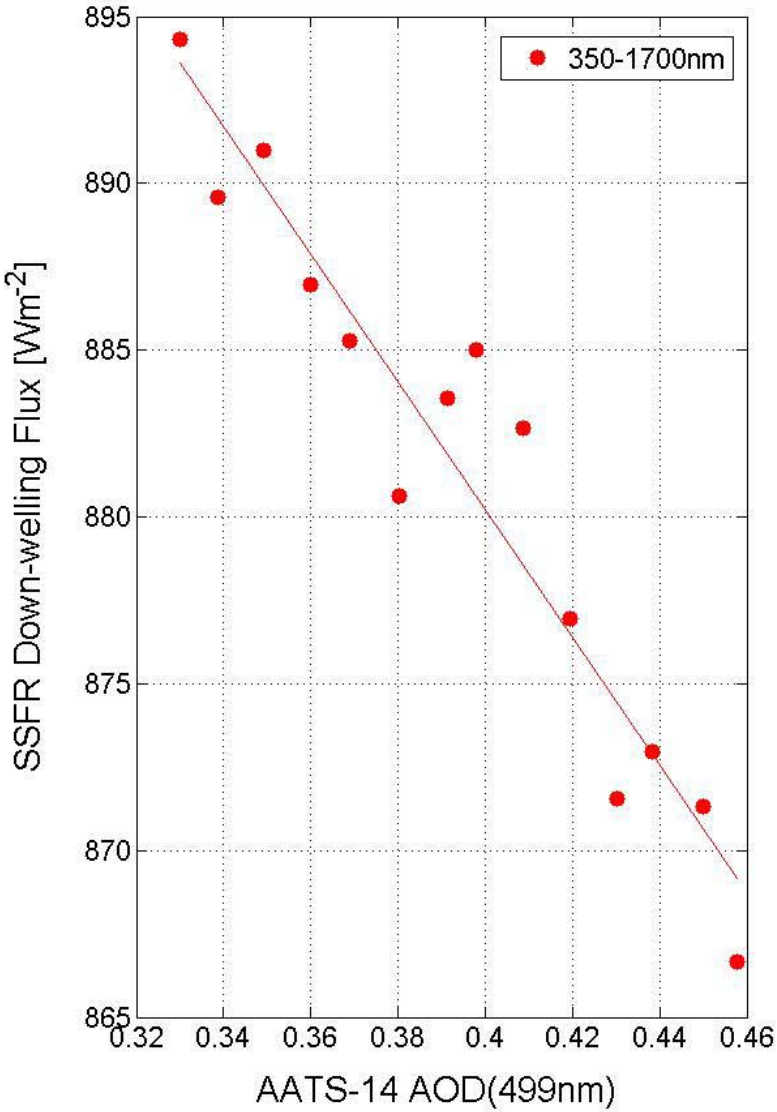
J31 Flight 12, 21 July 2004

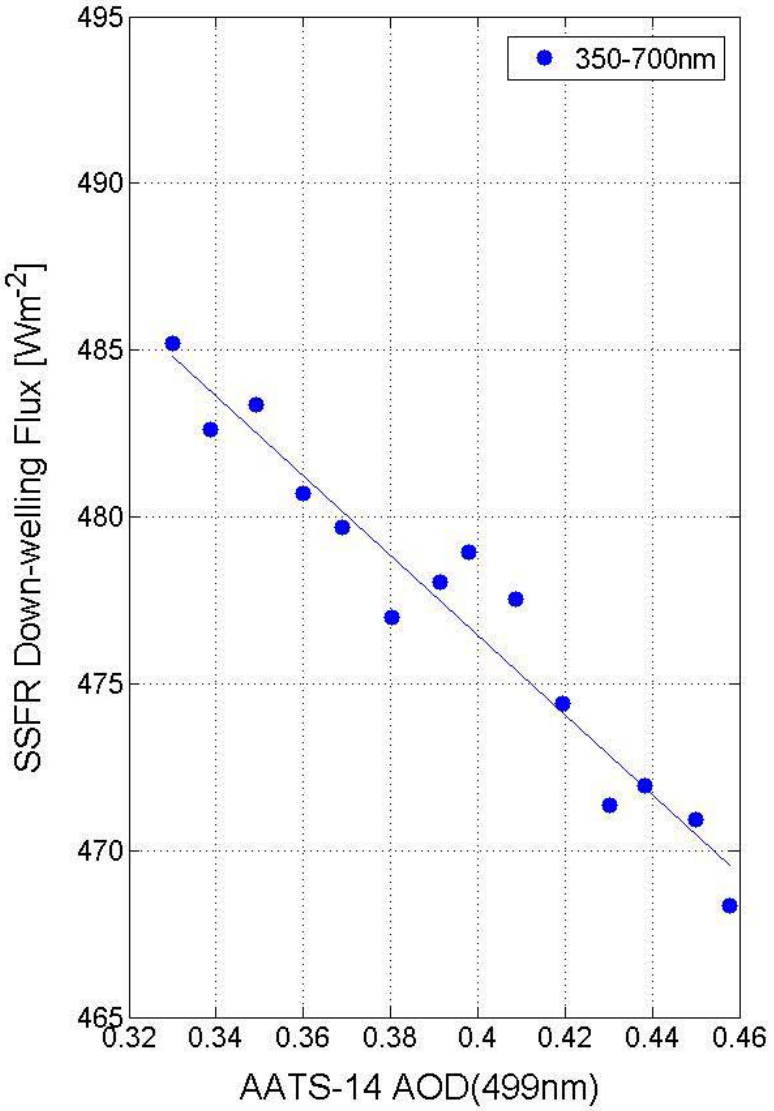


MODIS Aqua 21 July 2004, 1805 UT

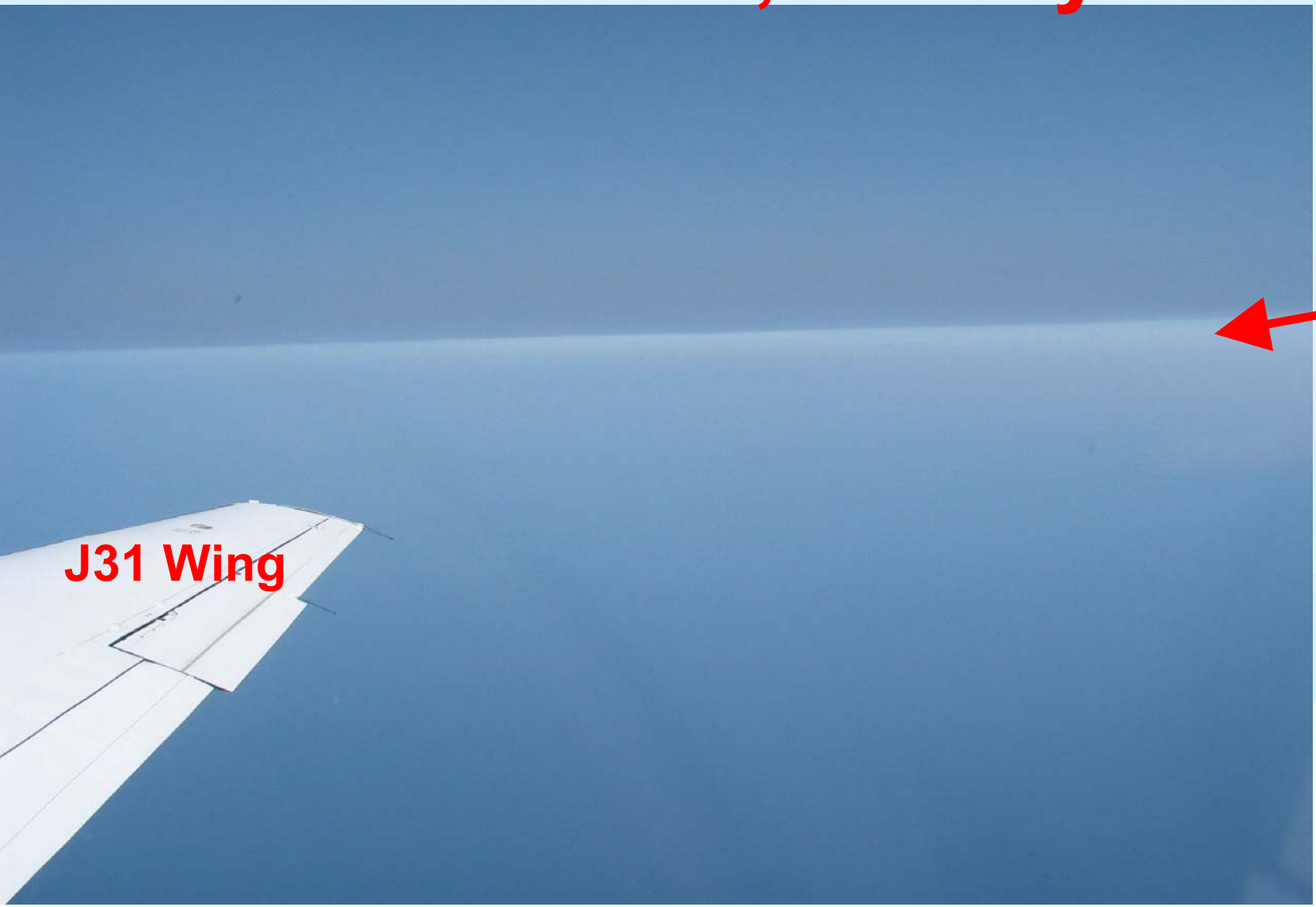
"Smoke From Alaskan Wildfires"

J31 Flight 12, 21 July 2004: Aerosol Gradient
SSFR Downwelling Flux vs AATS AOD





Haze above “clean layer” over Gulf of Maine, 22 July 2004



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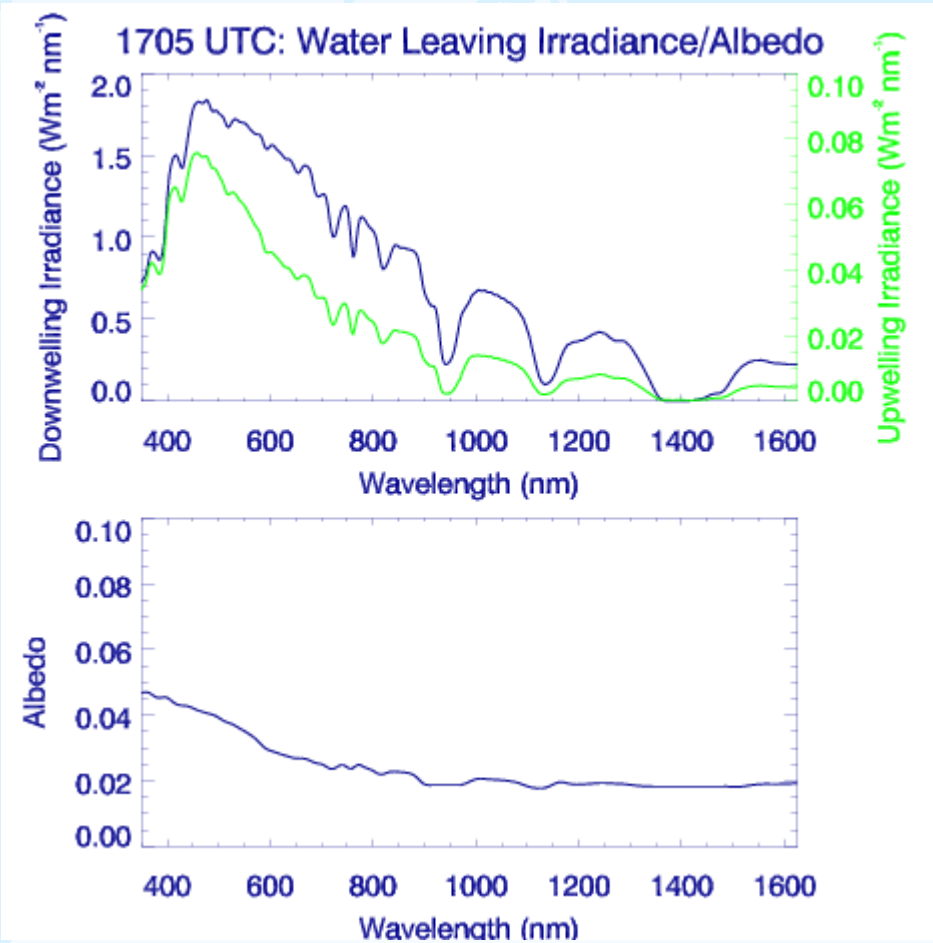
RV Ron Brown as seen from J31 flyby at 200 ft altitude, 17 July 2004

J-31: 17 July 2004



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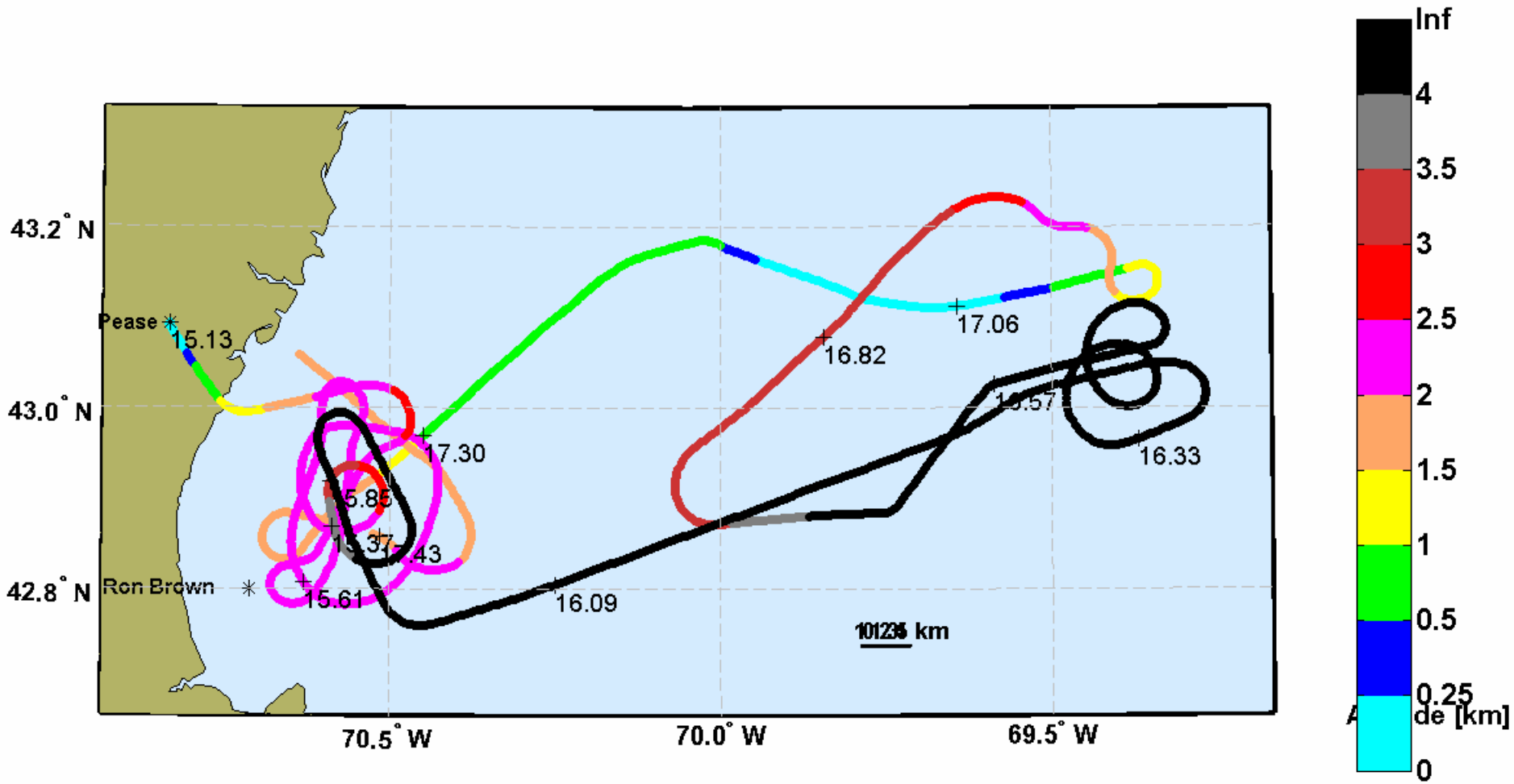
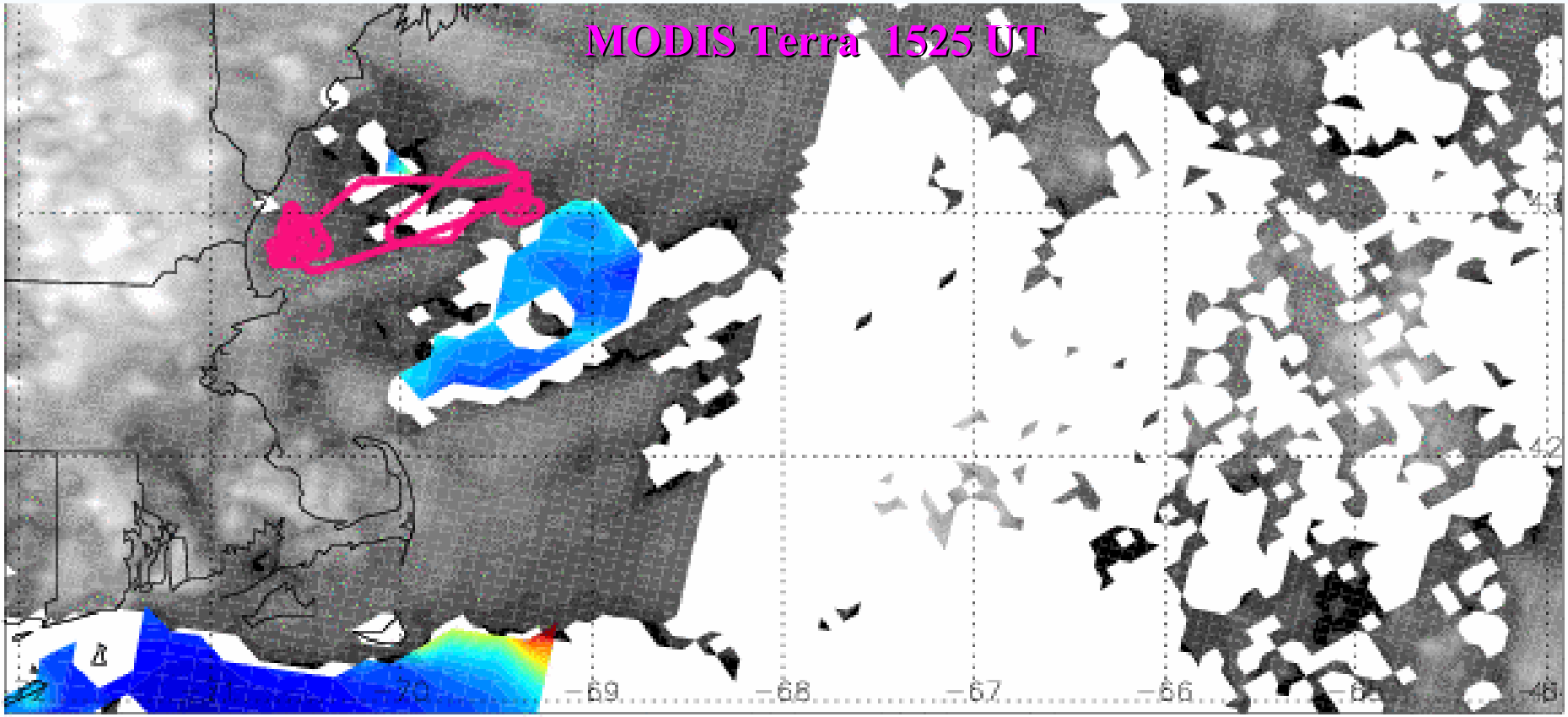
J31 Flight 8, 15 July 2004

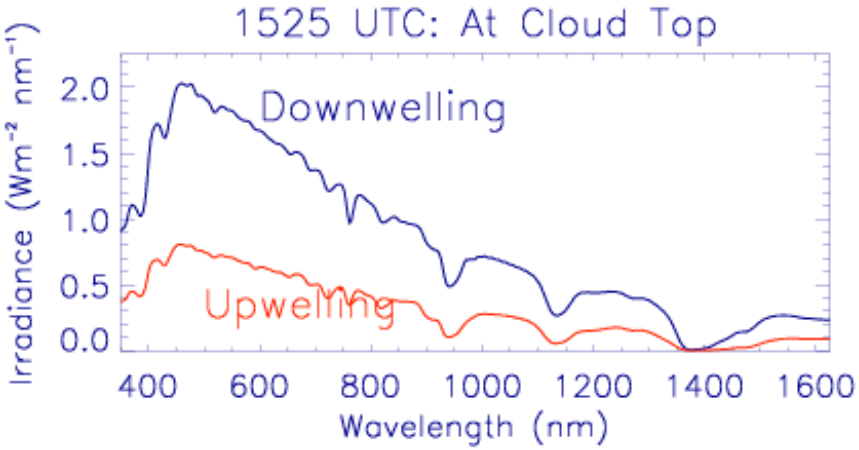


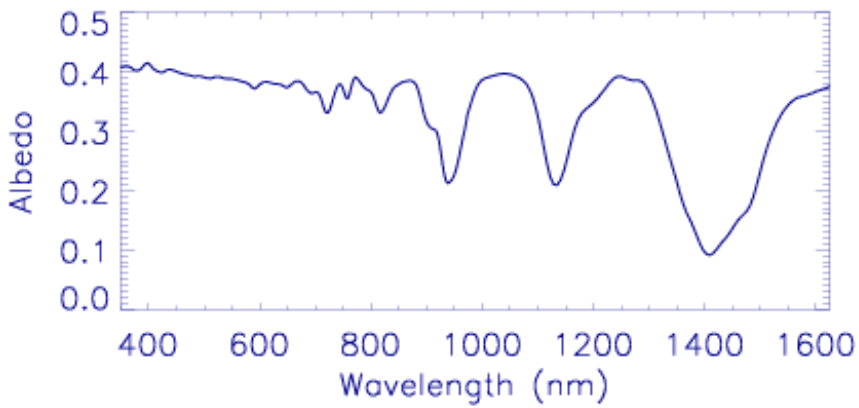
J31 Flight 8, 15 July 2004

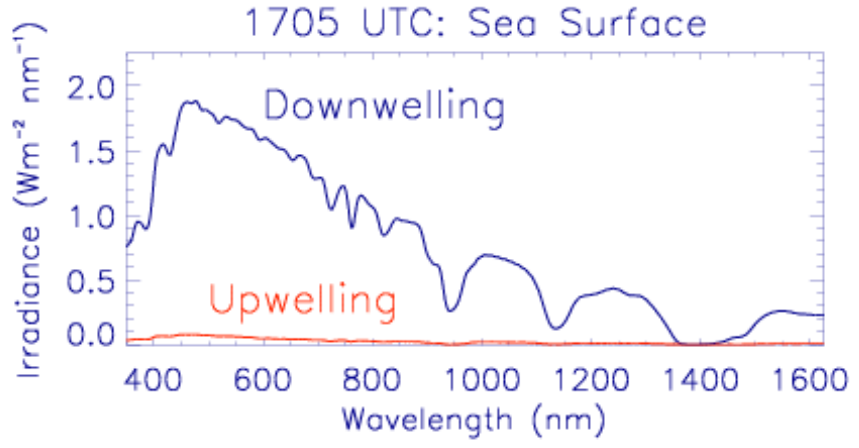


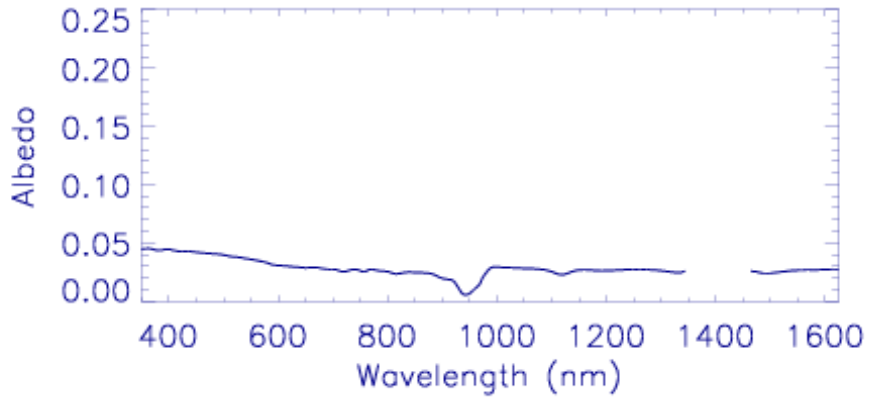
MODIS AOD, COT & J31 Track: L. Gumley, A. Chu, C. Kittaka, B. Pierce

J31 Flight 8, 15 July 2004
SSFR Results









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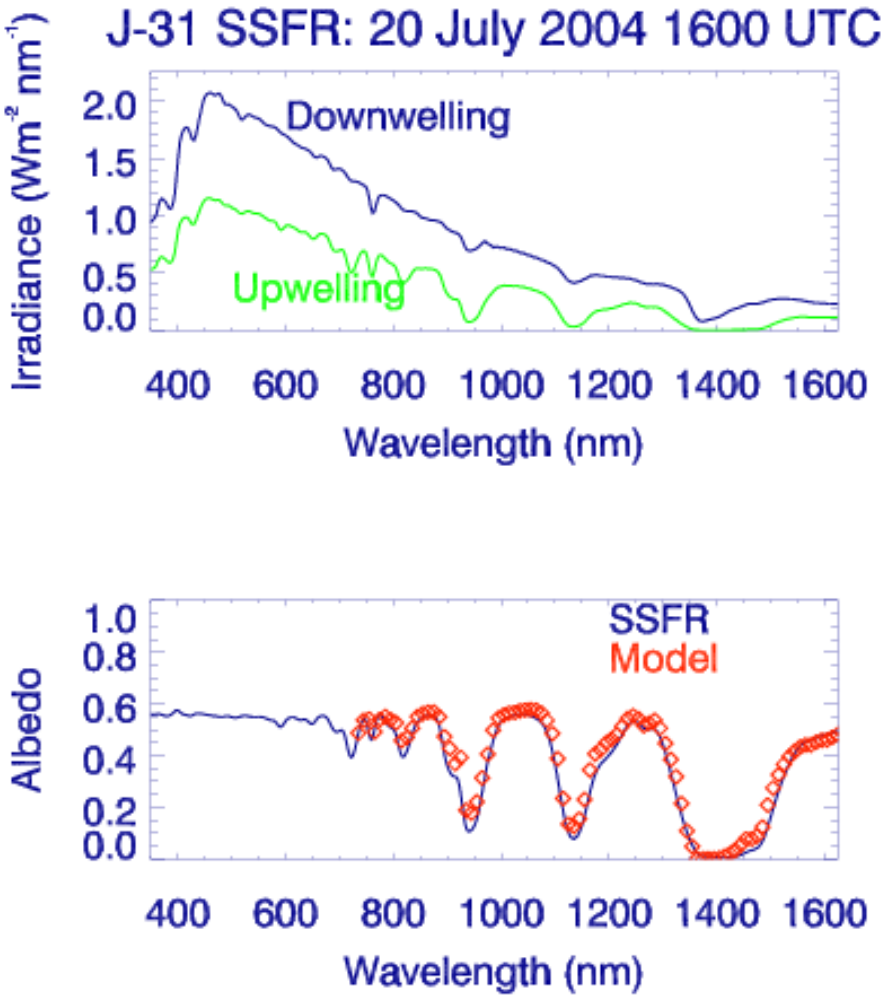
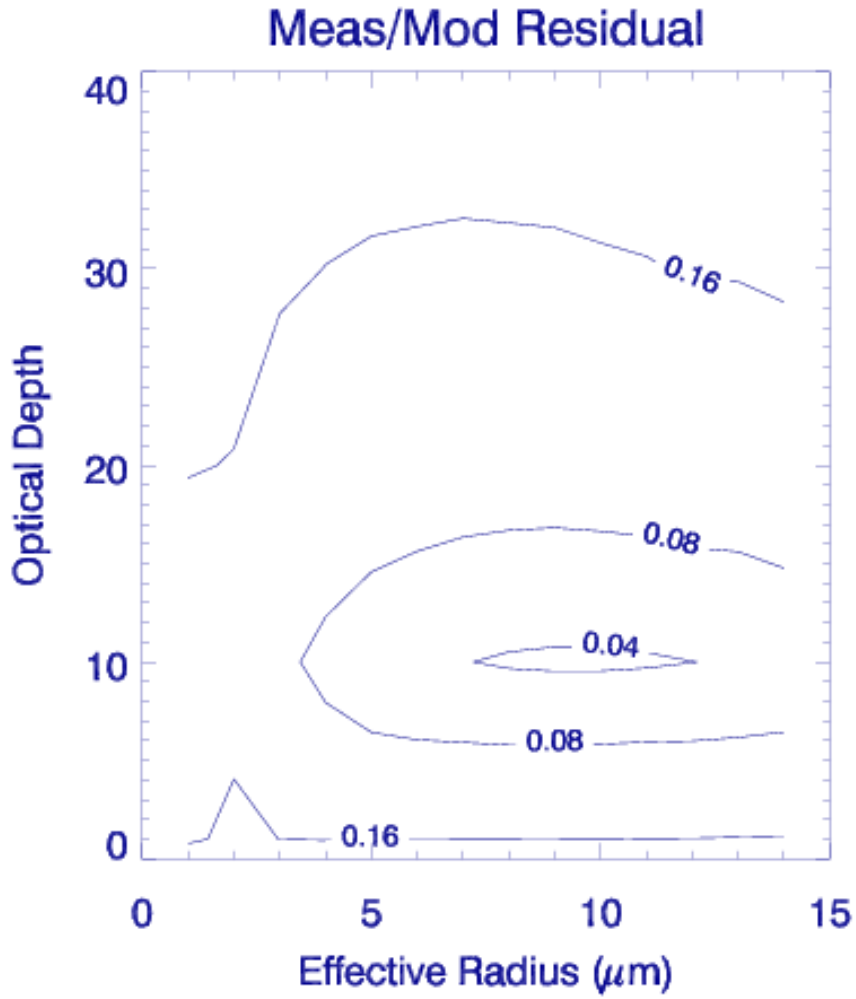
J31 Flight 11, 20 July 2004: SSFR Results

Stratus cloud optical depth and effective radius retrieved from irradiance spectra above cloud





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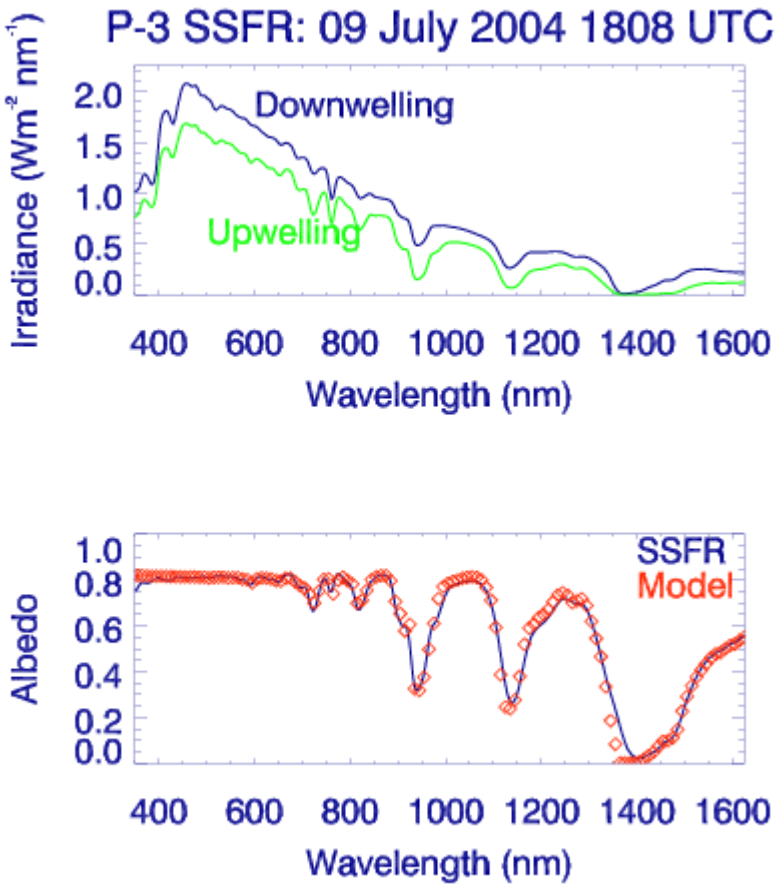
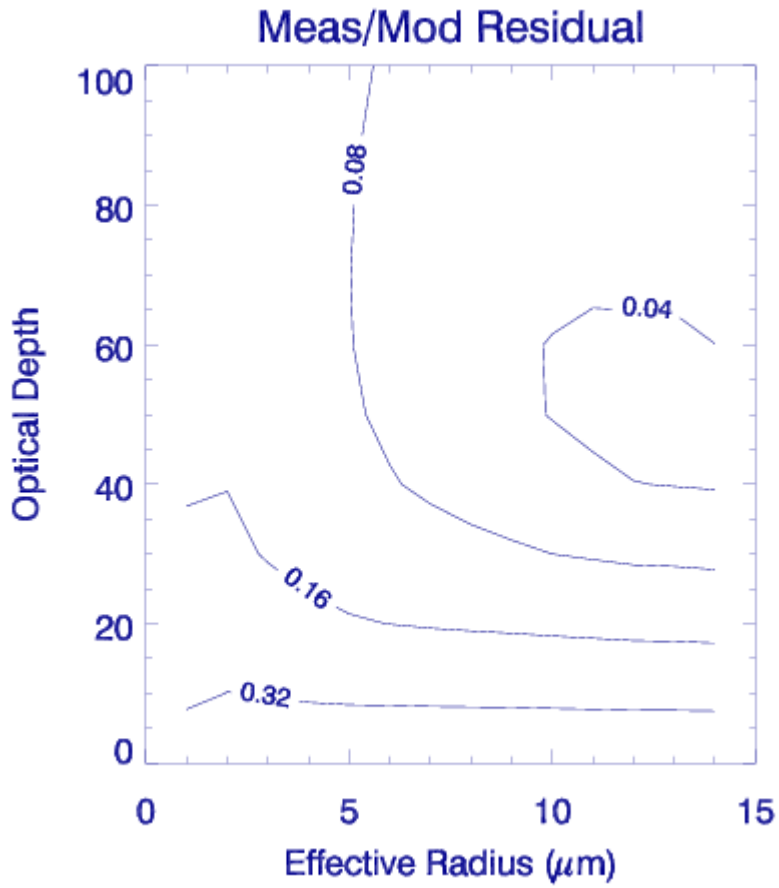
Cloud Retrievals: P-3





Looking Forward: What do we want to do more of in 2nd half of campaign?
(In rough priority order—highest first)

- Profiles in or near lidar beams (Ron Brown, DC-3, DC-8)
- Profiles with sondes
- MISR Local Mode with DC-8
- P-3 below & in cloud with J31 above
- More cases with AOD gradient. Can they be predicted?
- Flybys of Chebogue and/or AERONET sites
- Other Satellites: e.g., SCIAMACHY cloud retrievals

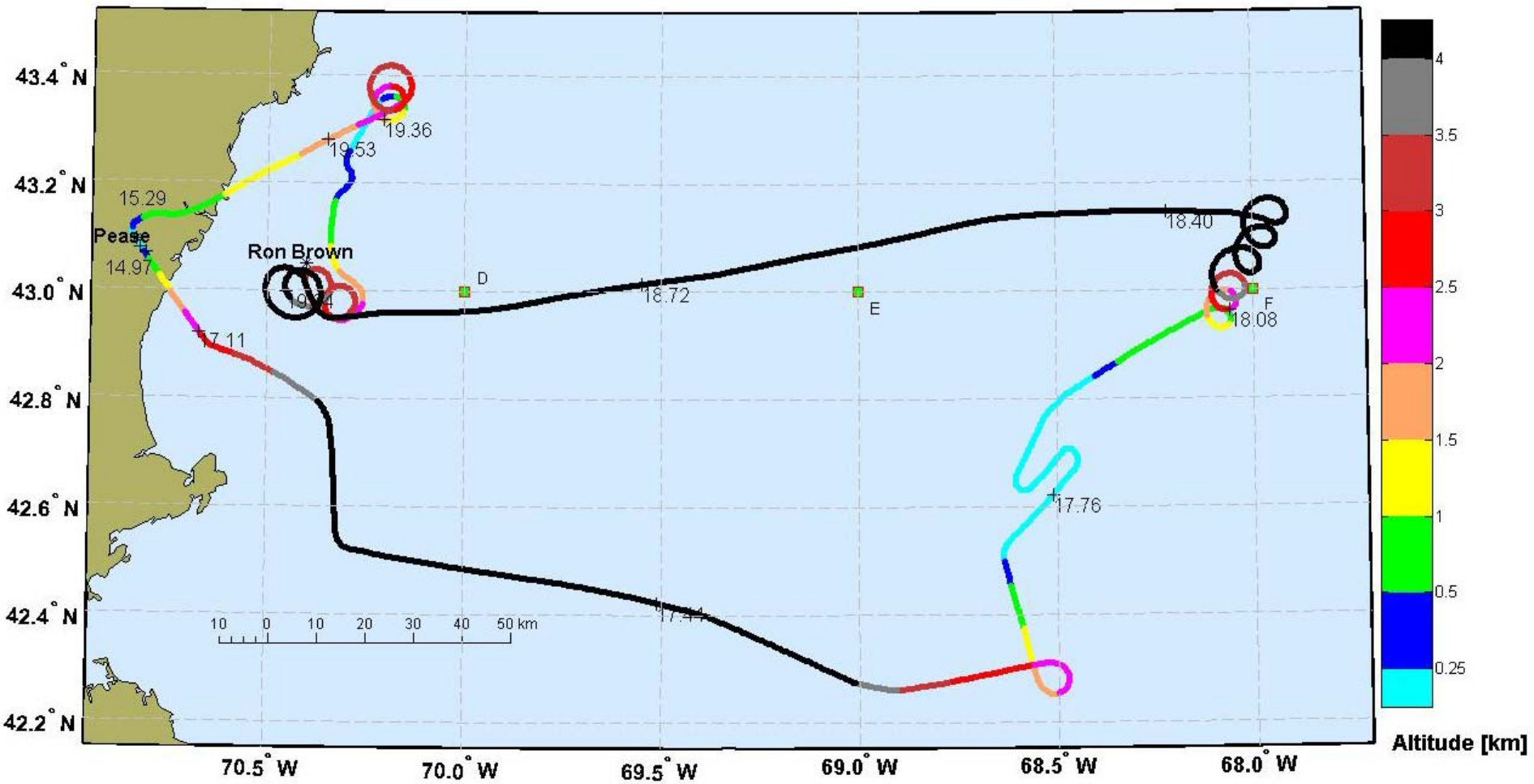
Jetstream-31 in INTEX-ITCT

End of Presentation
(Remaining slides are backup)

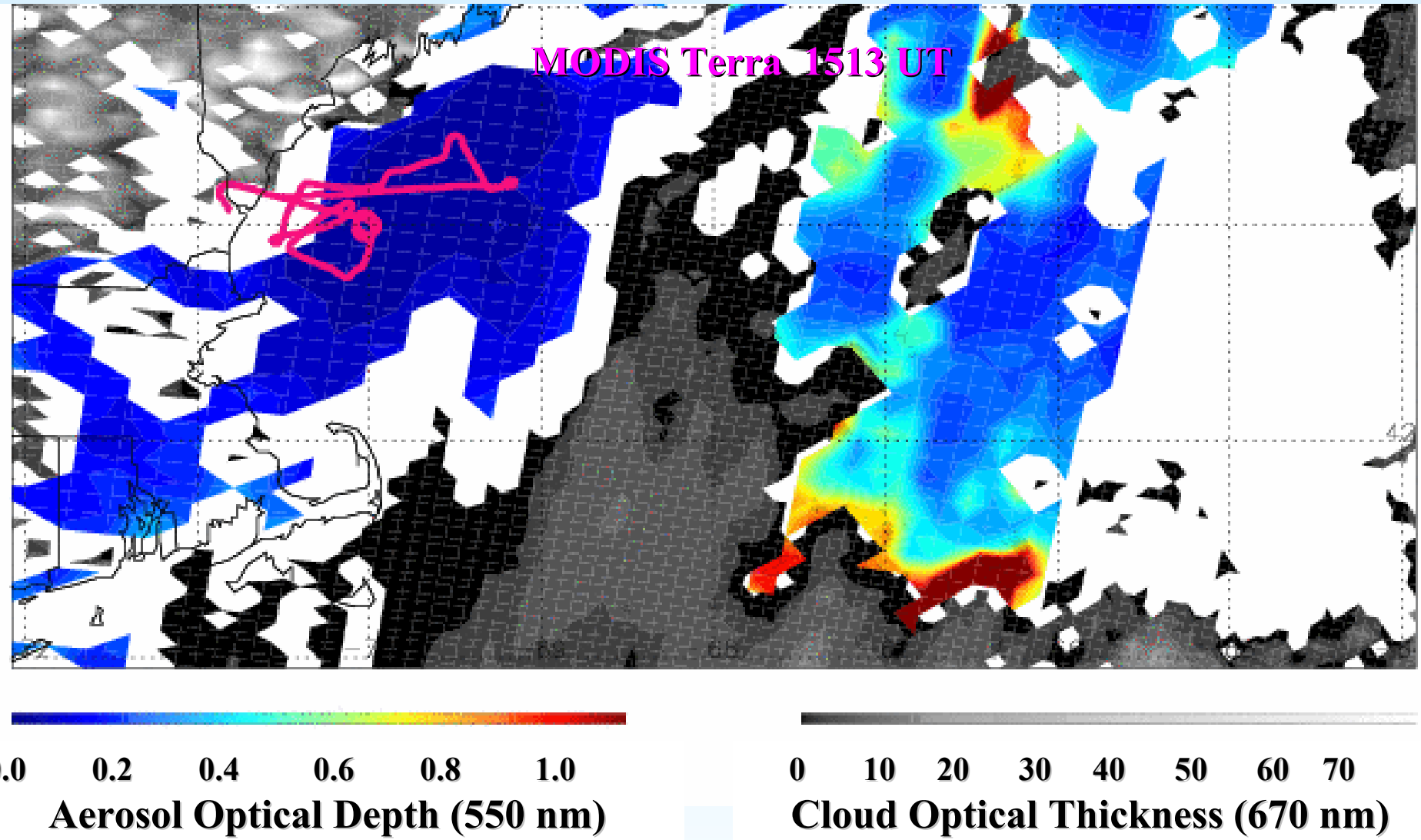
MODIS Aqua 21 July 2004, 1805 UT

"Smoke From Alaskan Wildfires"

J31 Flight 9, 16 July 2004

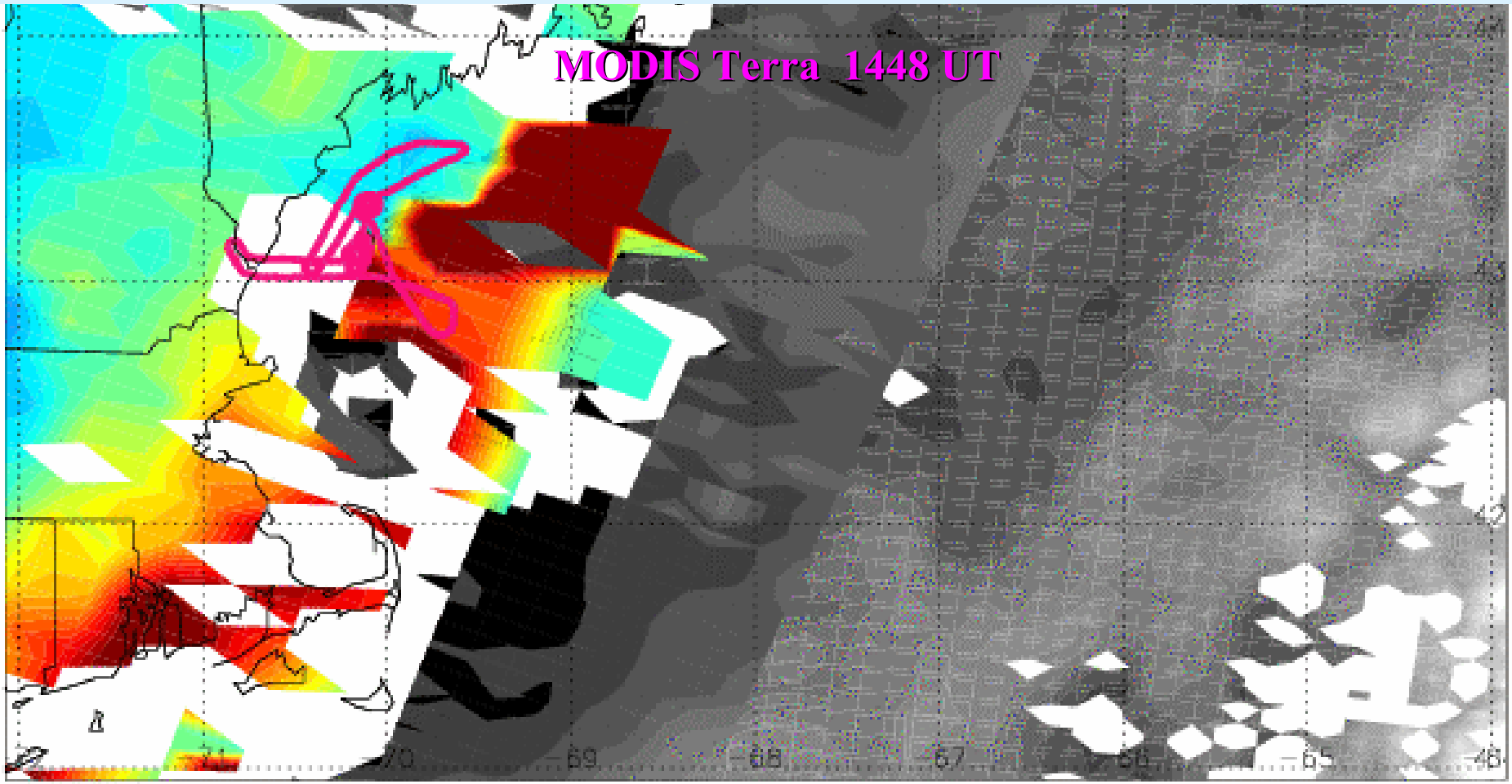


J31 Flight 10, 17 July 2004



MODIS AOD, COT & J31 Track: L. Gumley, A. Chu, C. Kittaka, B. Pierce

J31 Flight 12, 21 July 2004



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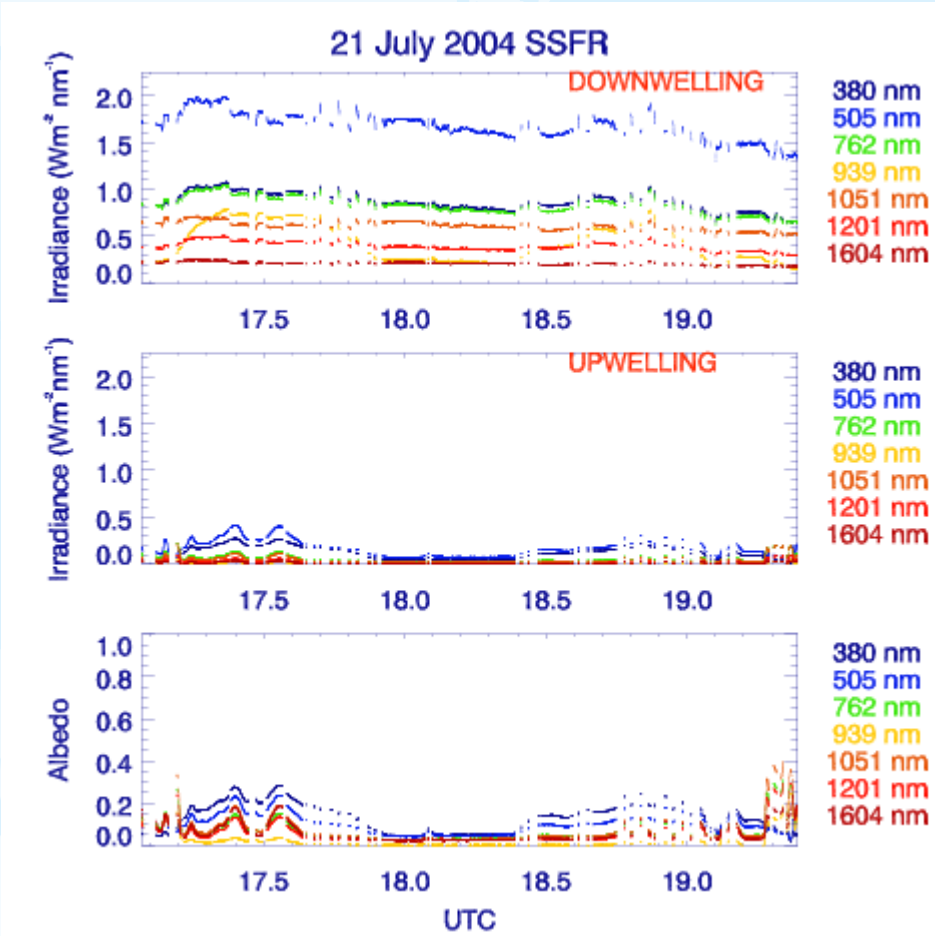
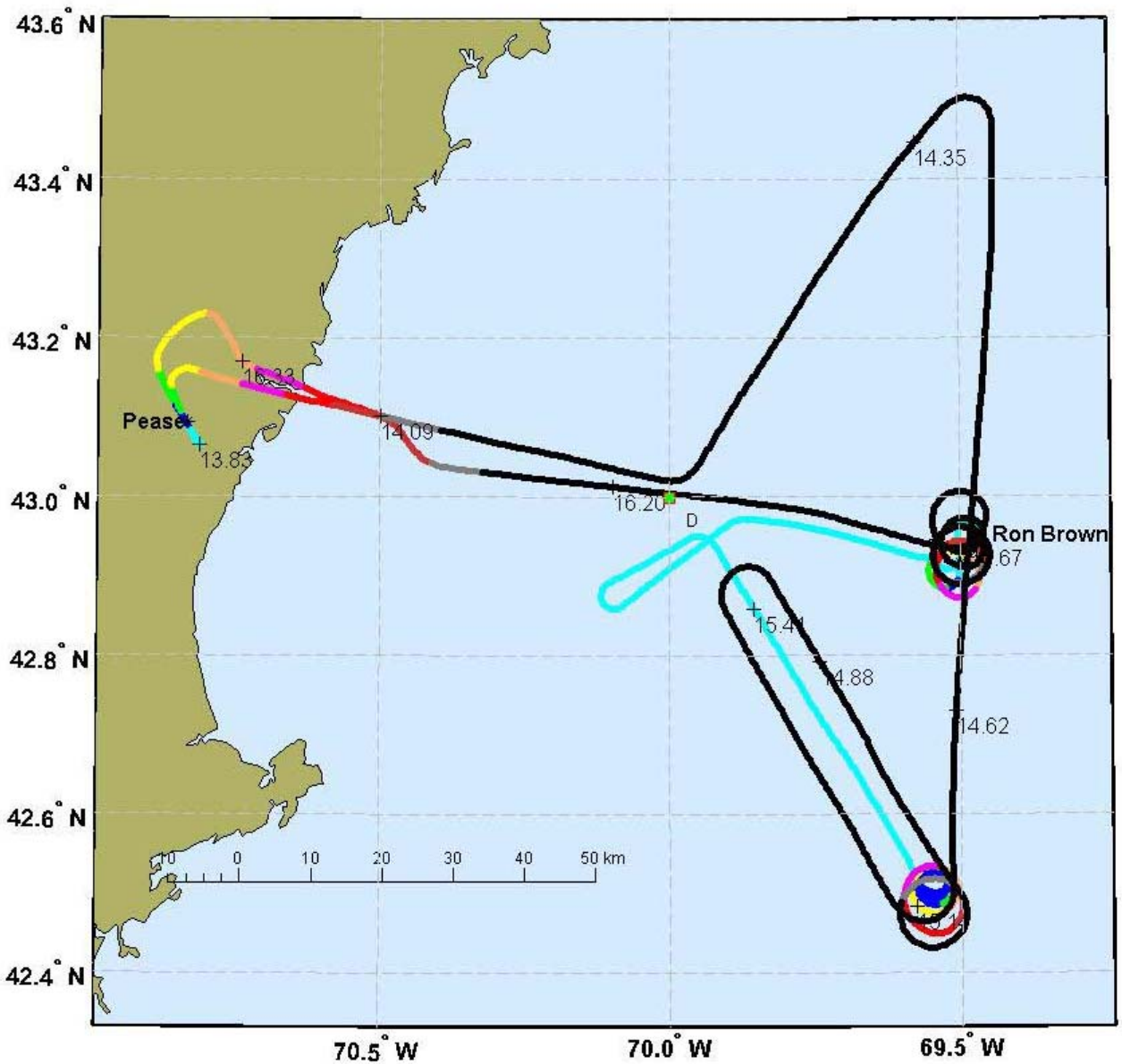
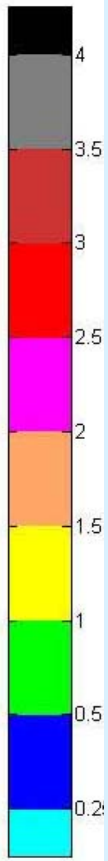
J31 Flight 12, 21 July 2004: SSFR Results

Irradiances and albedo. Over the very dark ocean surface, 1800-1820; clear above for the entire flight



J31 Flight 13, 22 July 2004





Terra 1531 UT (MISR Local Mode) w Ron Brown & DC-8

Jetstream-31 in INTEX-ITCT

Specs & Performance

Parameter	Specification
Length	47’ 2”
Wingspan	52’
Ceiling	25,000’
Airspeed	
Max cruise 16,000’	220 kt
Survey	150 kt
Range	850 nmi
Endurance	5 hr

SSFR measurements to determine absorption by an atmospheric layer

Downwelling Flux: $F\downarrow$

Upwelling Flux: $F\uparrow$

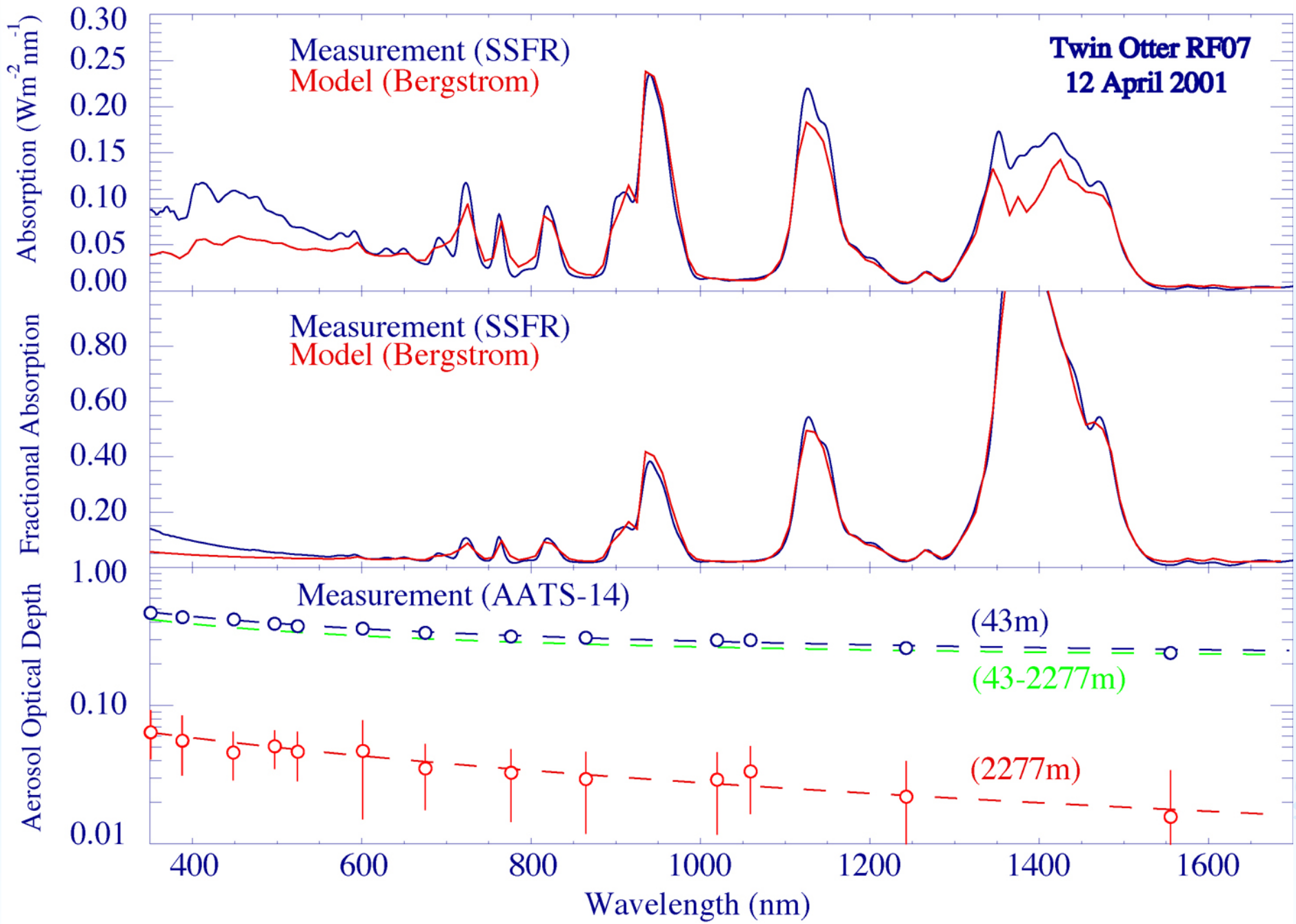
Net Flux: $F\downarrow - F\uparrow$

Flux Divergence (absorption):

$$(F\downarrow - F\uparrow)_{2000m} - (F\downarrow - F\uparrow)_{43m}$$

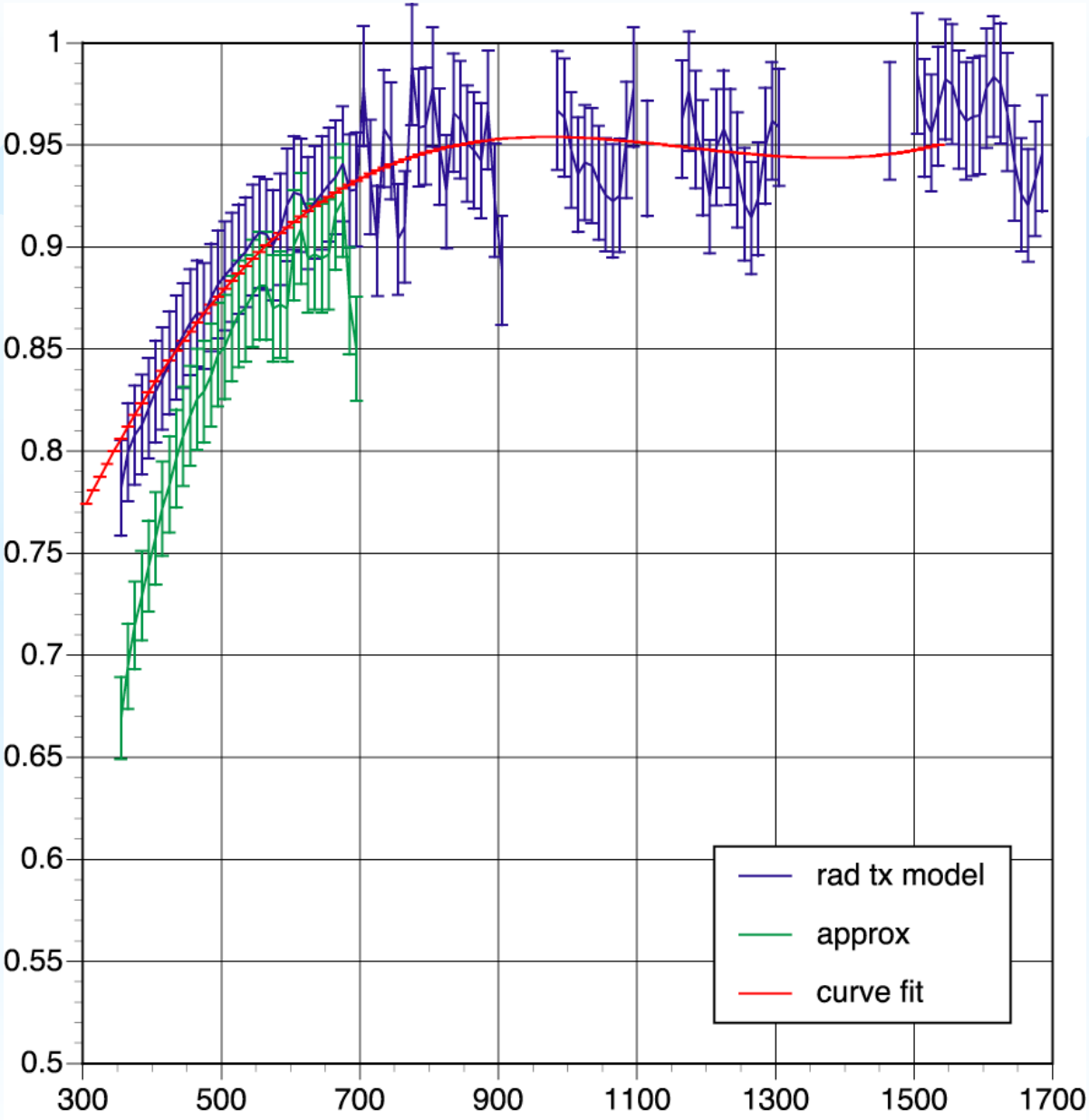
Fractional absorption:

$$[(F\downarrow - F\uparrow)_{2000m} - (F\downarrow - F\uparrow)_{43m}] / F\downarrow_{2000m}$$



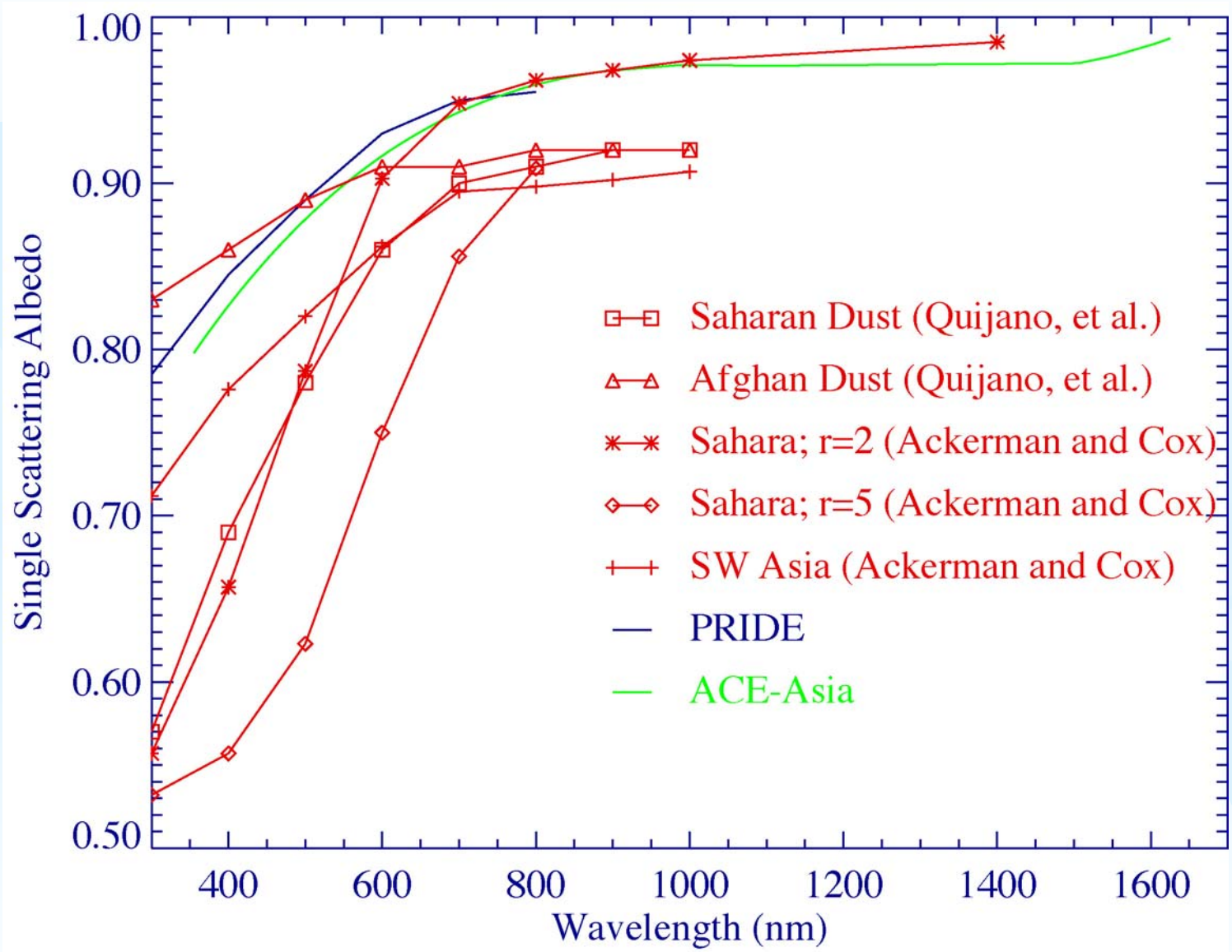
Pilewskie, Bergstrom, Schmid et al.

Aerosol Single Scattering Albedo Spectrum



Derived from measured flux and AOD spectra

Bergstrom, Pilewskie, Schmid et al.


1.00
0.90
0.80
0.70
0.60
0.50
Single Scattering Albedo
400
600
800
1000
1200
1400
1600
Wavelength (nm)
Saharan Dust (Quijano, et al.)
Afghan Dust (Quijano, et al.)
Sahara; r=2 (Ackerman and Cox)
Sahara; r=5 (Ackerman and Cox)
SW Asia (Ackerman and Cox)
PRIDE
ACE-Asia

Science Goals

- Study the radiative-climatic effects of aerosols in the context of the Summer 2004 experiments on transcontinental/ intercontinental flows
- Address the following INTEX & ITCT needs cited by INTEX White Paper and ITCT Plan:

- Airborne measurements of spectral optical depth (INTEX Table 2, Priority 2: Very important)

- Large-scale continental outflow characterization (Flight Type 4, p. 15) using our column measurements of aerosol OD and H_2O.

- Satellite validation (Flight Type 8, p. 15) using the same

- Integrated analyses that combine satellite and suborbital measurements to assess impacts of continental outflows on the larger-scale atmosphere and climate

- Other INTEX & ITCT goals, including characterizing outflow from US and Canadian fires, vertical profiling over ships and fixed sites from boundary layer to free troposphere, and inter-comparisons to test and validate measurements on multiple aircraft platforms.

Science Plans: Integrated Analyses

- Satellite Validation
- Testing Closure (Consistency) among Suborbital Results
- Testing Chemical-Transport Models
- Deriving Aerosol Absorbing Fraction (1-SSA) from Radiative Flux and AOD Spectra
- Assessing Regional Radiative Forcing by Combining Satellite and Suborbital Results

Cloud Retrievals: J-31